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Subject: Revised Costs for Secondary Chamber Retrofits for MWI's
            EPA Contract No. 68-D1-0115; Work Assignment No. 108
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I. <u>Introduction</u>

        This memorandum presents capital and annual costs of
combustion control retrofits for medical waste incinerators
(MWI's). Costs were developed to retrofit both 1/4- and 1-sec
secondary chambers with 2-sec secondary chambers.

II. <u>Capital Costs</u>

        The total capital investment (TCI) equals the sum of the
purchased equipment cost (PEC) and the installation cost. The
procedure to estimate the retrofit TCI is the same as that
described in the background documentation for the proposed
standard.[1] The equation used to calculate the TCI is shown in
Table 1. A summary of the procedure is described below.

        The PEC of a 2-sec secondary chamber was assumed to be
equal to two times the incremental cost between MWI's with 1-sec
and 2-sec secondary chambers. In background documentation for
the proposed NSPS and emission guidelines, the total capital
investment was presented in October 1989 dollars.[1] These costs
were scaled up using the Chemical Engineering Plant Cost Indexes
for July 1994 and October 1989. These indexes were 368.0 and
357.5, respectively.[2,3]

        The retrofit installation cost was assumed to be twice as
much as for a new facility because of the additional costs for
demolition and disposal of the existing secondary chamber. The
installation cost was assumed to be the same for retrofits of
both 1/4- and 1-sec secondary chambers because of variables that
could make either more expensive. For example, the additional
material to be demolished and disposed of could result in higher
costs for the retrofit of the 1-sec secondary chamber.
Alternatively, space limitations may make installation more
difficult and costly for a retrofit of a 1/4-sec secondary

TABLE 1. RETROFIT COMBUSTION CONTROL COSTS

Parameters\model combustors	Continuous MWI's		Intermittent models			Batch MWI
	Commercial	Onsite	large	medium	small	
1. Model parameters						
a. Design capacity, lb/hr	1,500	1,000	1,000	350	100	
lb/batch						500
b. Flow rate into control device, dscfm (a)	4,748	3,165	3,165	1,108	317	300
2. Total capital investment for SC retrofit, $ (b)	175,298	128,383	128,383	67,394	43,952	43,448
3. Downtime cost, $	86,760	9,045	7,537	784	214	302
4. Direct annual costs, $/yr						
a. Refractory replacement	1,753	1,284	2,568	1,348	879	869
b. Auxiliary fuel (c)	20,415	7,088	11,818	3,408	927	2,324
c. Maintenance materials	3,506	2,568	2,568	1,348	879	869
5. Indirect annual costs, $/yr						
a. Overhead (d)	2,104	1,541	1,541	809	527	521
b. Property tax, insurance, and administrative	7,012	5,135	5,135	2,696	1,758	1,738
c. Capital recovery (e)	19,492	14,275	13,471	7,071	4,612	4,559
d. Annualized downtime cost (f)	10,191	1,062	885	92	25	35
6. Total annual 2-sec SC combustion control retrofit cost, $/yr	64,472	32,954	37,986	16,772	9,608	10,915

(a) The flow rate is assumed to be the same for existing and retrofitted combustors.

(b) The TCI is the cost to remove the existing SC and retrofit a new 2-second SC.

(c) The design temperature is assumed to be 1800 F for the retrofitted 2-second SC and the existing 1-second SC, and 1700 F for the existing 1/4-sec SC. Auxiliary fuel includes both the cost for additional fuel to raise the secondary chamber temperature from 1700 F to 1800 F and the cost of fuel to maintain 1800 F in the secondary chamber during cooldown until the combustion air blowers are turned off ((for the 1/3 of intermittent MWI's affected).

(d) The overhead cost is based on 60 percent of the maintenance materials cost; the operating and maintenance labor costs are assumed to be the same for both existing and retrofitted combustors.

(e) The CRF is 0.11746, based on an interest rate of 10 percent and 20-year equipment life.

(f) Downtime cost is a one-time cost that was annualized over the 20-yr life of the retrofit equipment (i.e., it was annualized using the CRF).

chamber (i.e., the space around an existing 1/4-sec secondary chamber may be less than that around an existing 1-sec secondary chamber, thus making it more difficult to install a 2-sec secondary chamber in place of the 1/4-sec secondary chamber).

III. <u>Downtime</u>

An MWI would be unavailable for use while the retrofit work is being performed. For onsite nonbatch MWI's, this analysis assumes waste generated during as many as 3 days can be stored and burned after the retrofit is completed. During any remaining downtime, the facility would have to find other ways to dispose of the waste. For batch MWI's, it was assumed that no waste can be stored because the batch MWI's are assumed to be operating at capacity. For commercial facilities, the downtime would result in lost revenues that could not be recouped because the facilities are assumed to be operating at capacity.

The procedure for estimating the number of days of downtime is the same as in the background documentation.[4] The unit costs for alternative disposal and the procedure for annualizing the downtime cost are also unchanged. In addition, the downtime cost for retrofitting 1/4- and 1-sec SC's was assumed to be the same because, as noted above, installation costs (and time) can be variable. Equations used to calculate downtime costs are shown in Attachment 1.

IV. <u>Annual Costs</u>

Direct annual costs were estimated for refractory replacement, auxiliary fuel, and maintenance materials. The procedures to estimate the auxiliary fuel and maintenance materials costs are the same as in the background documentation.[5] Calculation of refractory replacement annual costs was simplified from the procedure in the background documentation. The detailed procedure is shown in Attachment 2. However, examination of these results shows the refractory replacement annual costs for intermittent and batch MWI's are approximately equal to 2 percent of the TCI for the 2-sec retrofit; 1 percent is applicable for continuous MWI's because most existing continuous MWI's are assumed to have a secondary chamber with a residence time of at least 1-sec. These simplifications underestimate the refractory replacement cost slightly for large MWI's and overestimate the cost slightly for small MWI's, but they have a negligible effect on the total annual cost.

Indirect annual costs were estimated for overhead, property taxes, insurance, administrative activities, and capital recovery. In addition, the downtime cost was annualized using the capital recovery factor. Overhead costs were increased because they are estimated to be equal to 60 percent of the maintenance materials cost. All of the indirect annual costs

were estimated using the same procedures that were described in the background documentation.[5]

Equations used to calculate annual costs are shown in Attachment 1. These equations are based on the operating hours described in Attachment 1. The basis for these hours is described in a separate memorandum.[6] Table 1 shows the results obtained with these equations for several representative model MWI's.

The equations also can be used to calculate costs for all MWI's in the nationwide inventory. The inventory does not distinguish between intermittent and continuous MWI's.[7] However, batch MWI's are a separate group. Commercial facilities also have been identified, and they are all assumed to be continuous MWI's. In addition, all MWI's with waste charging capacities up to 500 lb/hr are assumed to be intermittent MWI's. The remaining group of non batch MWI's was divided into intermittent and continuous units assuming the same distribution that was used in the background documentation for the proposed standards, which indicated intermittent and onsite continuous MWI's with capacities greater than 500 lb/hr are distributed in a ratio of about 3 to 1.[8]

V. References

1. U. S. Environmental Protection Agency. Medical Waste Incinerators - Background Information for Proposed Standards and Guidelines: Model Plant Description and Cost Report for New and Existing Facilities. EPA-453/R-94-045a. July 1994. pp. 107 through 109.

2. Economic Indicators. Chemical Engineering. Plant Cost Index for July 1994. October 1994. p. 214.

3. Economic Indicators. Chemical Engineering. Plant Cost Index for October 1989. January 1990. p. 216.

4. Reference 1. pp. 109 through 111.

5. Reference 1. p. 113.

6. Memorandum from D. Randall, MRI, to R. Copland, EPA:ESD. January 29, 1996. Operating Parameters and Costs for Model Medical Waste Incinerators.

7. Memorandum from B. Strong and B. Hardee, MRI, to R. Copland, EPA:ESD. January 31, 1996. Updated medical waste incinerator data base.

8. Reference 1. pp. 6 and 8.

2 Attachments

TABLE 2. REFRACTORY REPLACEMENT COSTS

Parameters\model combustors	Continuous MWI	Intermittent models large	Intermittent models medium	Intermittent models small	Batch MWI
1. Model parameters					
a. Design capacity, lb/hr lb/batch	1,000	1,000	350	100	500
b. Flow rate into control device, dscfm (a)	3,165	3,165	1,108	317	300
c. Operating hours, hr/yr (b)	4,050	3,500	2,533	2,363	3,600
d. 2-second SC parameters					
(1) Volume, ft3 (c)	502	502	176	50	48
(2) Diameter, ft	6.8	6.8	4.8	3.2	3.1
(3) Length, ft	13.7	13.7	9.6	6.4	6.2
e. 1-second SC parameters (d)					
(1) Volume, ft3 (c)	251	251	88	25	23
(2) Diameter, ft	5.4	5.4	3.8	2.5	2.4
(3) Length, ft	10.9	10.9	7.6	5.0	4.9
f. 1/4-sec SC parameters (e)					
(1) Volume, ft3 (c)	60	60	21	6	6
(2) Diameter, ft	3.4	3.4	2.4	1.6	1.5
(3) Length, ft	6.7	6.7	4.7	3.1	3.1
2. Total capital investment for SC retrofit, $ (f)	128,383	128,383	67,394	43,952	43,448
4. Direct annual costs, $/yr					
a. Refractory replacement for 1-sec existing SC	1,480	1,480	744	330	335
b. Refractory replacement for 1/4-sec existing SC	3,044	3,044	1,536	684	641

(a) The flow rate is assumed to be the same for existing and retrofitted combustors.
(b) Operating hours includes the preheat, burning, and burndown hours per year for all MWI's. Also included are average cooldown hours per year for intermittent MWI's that operate the combustion air blowers during cooldown.
(c) Based on assumed design temperature of 1800 F for the retrofitted 2-second SC and the existing 1-second SC and 1700 F for the 1/4-second SC.
(d) Gas residence time in the existing secondary chamber is 1 second.
(e) Gas residence time in the existing secondary chamber is 1/4 second.
(f) The TCI is the cost to remove the existing SC and retrofit a new 2-second SC.

Attachment 1

ALGORITHM FOR RETROFIT COMBUSTION CONTROL COSTS

A. Total Capital Investment

1. 2-sec SC retrofit cost = (28.80*dscfm+33568)*368.0/357.5
   = 29.65*dscfm + 34,554

B. Downtime Costs

1. Downtimes
   a. 2 days for nonbatch MWI's with design waste charging capacities up to 500 lb/hr.
   b. 5 days for nonbatch MWI's with design waste charging capacities greater than 500 lb/hr.
   c. 3 days for batch MWI's.
   d. 12 days for 1,500 lb/hr continuous commercial MWI's.

2. General cost equations
   a. Downtime cost for nonbatch MWI's, $ = ($0.3/lb)*(design lb/hr * 0.67)*(charging hr/d)*(downtime days)
   b. Downtime cost for batch MWI's, $ = ($0.3/lb)*(design lb/batch * 0.67)*(downtime days)

3. Specific cost equations
   a. Nonbatch MWI's up to 500 lb/hr, $ = 0.402*(design lb/hr)*(charging hr/d)
   b. Nonbatch MWI's greater than 500 lb/hr, $ = 1.005*(design lb/hr)*(charging hr/d)
   c. Batch MWI's, $ = 0.603*(design lb/batch)
   d. Continuous, 1,500 lb/hr commercial MWI's, $ = 2.41 *(design lb/hr)*(charging hr/d)

C. Retrofit Annual Costs

1. Refractory replacement
   a. For existing 1/4-sec SC, additional refractory replacement cost is equal to about 2 percent of the TCI for the 2-sec SC retrofit.
   b. $/yr for 1/4-sec SC = 0.02*((29.65*dscfm)+34,554)
      = (0.593*dscfm) + 691
   c. For existing 1-sec SC, additional refractory replacement cost is equal to about 1 percent of the TCI for the 2-sec SC retrofit.
   d. $/yr for 1-sec SC = 0.01*((29.65*dscfm)+34,554)
      = (0.297*dscfm) + 346

2. Natural gas

a. Operating temperature assumed to be 1700 in existing 1/4- and 1-sec secondary chambers
b. Additional $/yr to raise SC operating temperature from 1700 to 1800 F
   = (0.32BTU/lb/F)*(28.5 lb/lbmole)*(100F)*(lbmole/385ft3))*
   (ft3/1000 BTU)*($3.5/1000 ft3)*(dscfm/0.9)*
   (60min/hr)*(preheat, charging, and burndown operating hr/d)*(d/yr)
   = (0.000553)*(dscfm)*(preheat, charging, and burndown hr/yr)
c. Additional $/yr to maintain SC temperature in intermittent and batch MWI's at 1800 F during cooldown when combustion air blowers are on
   = (0.32 Btu/lb/F)*(28.5 lb/lbmole)*((1800F-300F)/2)*(lbmole/385ft3)*(ft3/1,000Btu)*($3.5/1,000ft3)*(dscfm/0.9)
   (60 min/hr)(average cooldown operating hr/d)*(d/yr)
   = (0.00415)*(dscfm)*(cooldown hr/yr)

Attachment 2

TABLE 1. Additional Refractory Replacement Costs for 2-sec Secondary Chamber

2-second SC refractory replacement
a. Assume SC for all combustor types are enclosed in cylindrical shell
b. Assumed L/D ratio = 2:1
c. 2-sec SC volume, ft3 = dscfm/0.9*2260R/528R*2sec*1min/60sec
d. 2-sec SC diameter, ft = (SC volume*2/3.1416)^0.3333
e. 2-sec SC length, ft = SC volume*4/(3.1416*(SC dia.)^2)
f. 2-sec SC refractory replacement cost, 2SRR =
  (3.1416/4*(((0.75ft+SC dia.)^2-SC dia.^2)*SC length)+(3.1416/4*SC dia.^2*4.5in*1ft/12in))*$127/1ft3*368.0/357.5
g. 2-sec SC insulation replacement cost, 2SIR =
  (3.1416/4*(((0.75ft+0.333ft+SC dia.)^2-(SC dia.+0.333)^2)*SC length)+(3.1416/4*SC dia.^2*2/12))*$43/1ft3*368.0/357.5

1-second SC refractory replacement
a. 1-sec SC volume, ft3 = dscfm/0.9*2260R/528R*1min/60sec
b. 1-sec SC diameter, ft = (SC volume*2/3.1416)^0.3333
c. 1-sec SC length, ft = SC volume*4/(3.1416*(SC dia.)^2)
d. 1-sec SC refractory replacement cost, 1SRR =
  (3.1416/4*(((0.75ft+SC dia.)^2-SC dia.^2)*SC length)+2*(3.1416/4*SC dia.^2*4.5in*1ft/12in))*$127/1ft3*368.0/357.5
e. 1-sec SC insulation replacement cost, 1SIR =
  (3.1416/4*(((0.75ft+0.333ft+SC dia.)^2-(SC dia.+0.75)^2)*SC length)+2*(3.1416/4)*(SC dia.+4.5/12)^2*2/12)*$43/1ft3*368.0/357.5

Additional cost for 2-sec refractory replacement (vs. 1-sec), AC2V1SC =
(2SRR+2SIR)-(1SRR+1SIR)

Additional annual cost for 2-sec refractory replacement (vs. 1-sec), AAC2V1SC = AC2V1SC*0.18744

1/4-second SC refractory replacement
a. 1/4-sec SC volume, ft3 = dscfm/0.9*2260R/528R*1/4sec*1min/60sec
b. 1/4-sec SC diameter, ft = (SC volume*2/3.1416)^0.3333
c. 1/4-sec SC length, ft = SC volume*4/(3.1416*(SC dia.)^2)
d. 1/4-sec SC refractory replacement cost, 1/4SRR =
  (3.1416/4*(((0.75ft+SC dia.)^2-SC dia.^2)*SC length)+2*(3.1416/4*SC dia.^2*4.5in*1ft/12in))*$127/1ft3*368.0/357.5
e. 1/4-sec SC insulation replacement cost, 1/4SIR =
  (3.1416/4*(((0.75ft+0.333ft+SC dia.)^2-(SC dia.+0.75)^2)*SC length)+2*(3.1416/4)*(SC dia.+4.5/12)^2*2/12)*$43/1ft3*368.0/357.5

Additional cost for 2-sec refractory replacement (vs. 1/4-sec), AC2V1/4SC =
(2SRR+2SIR)-(1/4SRR+1/4SIR)

Additional annual cost for 2-sec refractory replacement (vs. 1/4-sec), AAC2V1/4SC = AC2V1/4SC*0.18744